DOUGLAS AIRCRAFT COMPANY, INC.

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UNCONVENTIONAL PROPULSION SCHEMES

PART 2 REV. 3-1-55

SANTA MONICA DIVISION

## APPENDIX I

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## IONIC PROPULSION

TITLE: 1. "WEGE ZUR RAUMSCHIFFAHRT" ("WAYS TOWARDS SPACE TRAVEL") *) -001

by Hermann Oberth
publ. by R. Oldenbourg, München - Berlin 1929 (in German).

(reproduced by J. W. Edwards, Edwards Bros., Ann Arbor, Mich., 1945, under license of Alien Property Custodian)

2. "ELECTRIC SPACE SHIPS" -002

by Professor Hermann Oberth
(in English)

publ. in Radio-Electronics (Radcraft Publications, Philadelphia, Pa.) Dec. 1950, p32 ff and vol. XXII, Jan. 1951, p74 ff.

### DAC ABSTRACT AND COMMENTS

Most of the book (Serial #001) is devoted to liquid fuel rockets, fundamental principles, dynamics, control and astronautic speculations. Only the last (22nd) chapter, 15 pages, deals with what today would be called an unconventional method of propulsion: viz. ionic; he called it "electric propulsion".

Already on p. 110 Oberth states categorically that contemporary science knows of three devices which would, theoretically, permit impelling a vehicle to escape velocity: the rocket, the electromagnetic gun (firing from a fixed emplacement) and the electric wind engine. He admits (p. 111) that electric propulsion from take-off would entail "gigantic" expenditures. However, as soon as a satellite station is established on a supra-atmospheric orbit, he advocates (p. 409 ff) electric propulsion as a means to produce two to ten times greater exhaust velocities than by chemical rocket engines and thus attain the speeds necessary for fast interplanetary travel. Oberth (on p. 412, 416) explains his electrical propulsion engine essentially as follows: solar radiation energy is collected by means of concave mirrors, concentrated upon boilers in which a working fluid is vaporized. This is made to do work in a multistage steam turbine and then condensed in a condensor and fed back into the boilers. The turbine drives an electrostatic generator. (Oberth quotes another proposal by Ulinski who wants to generate the electric current by thermopiles without rotating machinery.) The electric current thus generated builds up and maintains a voltage difference between a flat hot anode and a

*) An earlier edition of this book entitled "Die Rakete zu den Planetenräumen (The Rocket to the Planet Spaces) by H. Oberth was issued by the same publisher in 1923 and 1926.

grid-like cathode in an open Geissler tube type of impelling chamber where the gas is ionized and the ions impelled. He computes the momentum of the mass of ions repelled from the cathode (and like "canal rays" passed through the meshes of the cathode). He implies (but does not explain) that a continuous flow of working fluid is squirted in liquid form into the chamber where it is vaporized and ionized. As to the electrons which are freed at the same rate as the ions, Oberth justly discounts their negligible momentum and assumes the machine would get rid of the increasing negative charge by thermal emission.

Oberth computes that per 1 $m^2$ mirror area (in the vicinity of Earth) a 17% efficient steam engine can generate about 1/3 HP. Assuming an average exhaust velocity of 10 km/sec and .75 to .8 "efficiency", and estimating, rather optimistically, that he can build a non-gravity-encumbered space ship for only 1 kg per $m^2$ mirror area, hence about .7 lbs per HP (!) he finds he can accelerate it up to .004 g, not very much but enough to accumulate 3.6 km/sec velocity in one day, during which the ship would expel 43% of its end mass in the form of working fluid. By accelerating still more slowly the mass loss can be further economized in exchange for sacrifice of time. Oberth waxes quite enthusiastic about this type of interplanetary vehicle but only for travel between satellite stations or asteroids. He realizes that it would be too frail to submit to take-off or landing maneuvers on planets with substantial gravity.

He does however, speculate (p. 421-422) about a fantastic alternative, namely to transmit beamed radiation power from terrestrial or satellite-borne antenna stations to interplanetary vehicles carrying ionic propulsion engines.

NOTE 1: The author (then a high school teacher in the small Hungarian town of Mediasch) is recognized as one of the grand old pioneers of rocketry. The book (Ref. 1) is one of the "classics" on the subject; it was, though quite replete with caustic polemics against the author's contemporary scientific opponents or rivals, awarded The Robert Esnault-Pelterie-Hirsch prize by the Astronautic Society of France.

NOTE 2: In more recent utterances and lectures (1950, 1952) Oberth has repeatedly indicated that he still believes in the merits of ion beam propulsion and he made mystifying remarks about recent experimental progress in this direction. During 1951-53 he worked for the Italian Navy in La Spezia.

Serial #002 is a popular magazine article, obviously prepared by translation and condensation of the content of Chapter 22 of the book Serial # 001, rearranged and better illustrated. The numerical assumptions on which the computations presented in the magazine are based, differ but slightly from those adopted in the German book.

Listings: LIA:052-2 (Ser. 001); 760-1 (Ser. 002)
A-GC: 329 (Ser. 002)

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IONIC PROPULSION

Title THE THRUST AVAILABLE FROM ELECTRONIC ACCELERATORS

Author: George F. Forbes

Source: Journal of Space Flight, Dec. 1952

## AUTHOR'S SUMMARY

"Mathematical analysis is presented for the propulsion of a space craft by ion streams. Power available, thrust, accelerating voltage, ion stream current, effect of non-ionized material, and velocities obtainable are considered together with efficiencies and other relevant factors.

"The mathematical presentation is intended primarily for engineers concerned with such a thrust source. No attempt is made to deal with the mechanical, electrical, and thermal difficulties involved in generating such a stream.

"An illustrative example is worked out to compare a cargo and passenger type craft using basically the same type of motor."

## DAC COMMENTS

As noted in the summary, the author is not concerned with the important and difficult engineering problems of producing the ion stream discussed. Assuming the availability of the required "fuel", an inert ion gas, and a suitable means of accelerating such ions before ejection, he proceeds to perform a rather elementary mathematical exercise, describing the general conditions of an ion propulsion system. The following quantities are discussed and/or employed in the two examples examined, viz. space journeys of a cargo and a passenger craft propelled through space by ionic exhaust.

| | |
|---|---|
| Ion accelerating power: | 1340 HP (100,000 volts at 10 amperes) |
| Mass of ship considered: | 20,000 kg. |
| Ratio of "fuel" to ship mass: | 0.05-0.1 |
| Mass of initial "fuel" load: | 1000-2000 kg. |
| Efficiency of propulsion system: | 50% |
| Acceleration of ship: | 0.1--1.0 cm/sec$^2$ |
| Thrust of ion motor: | 2x10$^7$ dynes (45 lbs) |
| "Fuel" (ion mass) consumption: | 0.2-20 g/sec = 38.15-3815 lb/day |
| Ship velocity (after all "fuel" is consumed): | 1.04-5.13 km/sec<br>= 3,400-17,000 ft/sec<br>= 55,000-280,000 miles/day |
| Proton/electron mass ratio: | 1840 |
| Ratio of atomic weight to charge of ions in exhaust: | 1,900-190,000 |
| Velocity of ejected ions relative to ship: | 10-100 km/sec |
| Time to consume all "fuel": | 53-1.16 days. |

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The examples assume that some auxiliary system has lifted the ship from the Earth and that the ion propulsion system is only for travel through space. "Tugs" would be employed to land the ships at their destinations.

The mathematical treatment is valid, but only serves to acquaint one with some of the mechanics of ionic propulsion.

REFERENCES

1. G. F. Forbes, "The Trajectory of a Powered Rocket in Space", JBIS 9 (2) March 1950
2. G. F. Forbes, "Application of the General Trajectory Equations", JBIS 10 (5) September 1951
3. H. Preston-Thomas, "Interorbital Transport Techniques", JBIS 11 (4) pp 173-193, July 1952
4. L. R. Shepard, "Interstellar Flight", JBIS 11 (4) pp 149-167, July 1952

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Listings: LIA 761-2
A-GC 1279

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NUCLEAR PROPULSION

IONIC PROPULSION

Title: INTERORBITAL TRANSPORT TECHNIQUES (with special reference to solar derived power)

Author: H. Preston-Thomas, Ph.D., B.Sc.

Source: Journal of the British Interplanetary Society, 11 (4), July 1952, pp 173-193

## AUTHOR'S SUMMARY

"This paper discusses the modus operandi of a transport system in space that has its economic justification in supplying Earth with a proportion of the rare and semi-rare metals and minerals that it needs. The writer considers that such a system, in which the transport is effected at very low cost, will be needed if space travel is to extend beyond the very occasional scientific expedition. The existence of methods of effecting such transport will also provide an incentive in addition to the present ones, which may be classed as military, scientific and telecommunication interests, for the establishment but will deal with the types of ship that operate from such a satellite, collect the raw materials and return them to Earth."

## DAC ABSTRACT

### ECONOMICS

Table I cites the approximate annual world production and cost of certain expensive metals. The author briefly discusses some of the hypothetical extra-terrestrial extraction benefits, such as unlimited thermal power, and vacuum techniques conveniently employed. On the other hand, lack of water and of atmospheric gases as well as different ore formation and storage may complicate the picture.

### METHODS OF PROPULSION

Consideration of transport of large quantities of material at tolerable cost, in the author's opinion, limits propulsion to the use of a mixture of monatomic and diatomic hydrogen at a chamber temperature of 3000 - 4000°K with the heating being by solar radiation, with some preheating derived from atomic energy or, less likely, solely by atomic energy. Electrically-accelerated ion propulsion systems, powered either directly or indirectly from solar or atomic power are possibilities. The use of thermocouples, photocells, and electric fields established by $\beta$- or $\alpha$-particles are considered less promising.

TRANSIT TIMES AND ACCELERATION REQUIREMENTS

On an interplanetary journey such as one from an Earth satellite station to the low-gravity satellite of Mars, Deimos, Preston-Thomas indicates that space ships need not be strongly braced, since accelerations of the order of one milligravity or less will suffice. The transit time would be 150-200 days.

GENERAL DESIGN DATA

Considering a typical ship, of 1000 tonnes mass (M.), the author discusses the ship's average acceleration A (in km/sec/day), the ship's characteristic velocity V (in km/sec), the specific mass in kg. of power plant per kW of power output (Mk) and the ship and fuel masses.

THE ION GUN

Propulsion by ion gun is deemed the most promising approach. The author considers powers of the order of 10,000 kW are necessary and feels that a high conversion efficiency such as 70% is possible. Various ion sources (References 4, 5, 6, and 7) are discussed and a mass/power ratio of 1/2 g/kW is held feasible. Many ion guns in parallel on one vehicle are envisaged.

ELECTROSTATIC GENERATORS

A modified generator of the van de Graaff type (Ref. 8) is advocated as probably the best solution to the problem of furnishing the electric power to the ion gun. A "Finkelstein source" is recommended to promote ionization.

DIRECT ATOMIC DRIVE (Current Source)

The principle of transfer from emitter plates to collector plates of electric charge carried by $\beta$-particles (Ref. 9) to feed to the ion guns is discussed and illustrated in a diagram (Fig. 5). Table II of long lived fission products indicates that Strontium 90, with a 5.3% yield, a half life of 25 years, and a maximum $\beta$ energy of 0.61 Mev is the most promising source. The contribution of such a system to the over-all specific mass should be small, 2 kg/kW or less. A vast, expensive atomic energy program would be required to realize such power plants.

SOLAR THERMOPILE POWER SYSTEM

The majority of metals providing high thermoelectric powers (Sb, Bi, Se, Te, Si) all have comparatively low melting points and therefore are not useable at high temperatures. A good thermocouple, consisting of lead sulphide against an alloy of zinc and antimony yields an efficiency of only 7 percent. New and, as yet, untried thermocouples have higher efficiencies at temperatures approaching 1000°C. The author describes and discusses a solar thermopile system comprising